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The imported fire ants, *Solenopsis invicta* Buren and *S. richteri* Forel (hereafter referred to as fire ants) were introduced into the United States in the early 1900s and currently inhabit more than 320 million acres (129.5 million ha) in the southern United States and Puerto Rico (Lofgren 1986a, Callcott and Collins 1996, Code of Federal Regulations 2001). Fire ants have continued to spread rapidly and now are established in California and New Mexico. The present quarantine map for fire ants (USDA-APHIS, 2003) and their potential range (Korzukhin et al. 2001) are shown in Figure 1.

Fire ants have become a dominant terrestrial arthropod (Macom and Porter 1996) causing a multitude of problems for humans, domestic ani-

mals, and agriculture (Adams and Lofgren 1981). Between 30 and 60% of the people in the infested areas are stung each year, with anaphylaxis occurring in 1% or more of those people (deShazo et al. 1990, 1999; deShazo and Williams 1995), suggesting that more than 200,000 persons per year may require a physician's aid for fire ant stings. Heavy losses in agricultural products such as hay, soybeans, and cattle, reaching into hundreds of millions of dollars, are well documented (Adams et al. 1983, Lofgren 1986b, Thompson et al. 1995, Barr and Drees 1996, Lard et al. 2002). In addition, imported fire ants destroy many other ground-inhabiting arthropods and other small animals, reducing the biological diversity in many areas (Porter and Savignano 1990, Vinson 1994, Jusino-

Atresino and Phillips 1994, Wojcik 1994, Wojcik et al. 2001).

Although the current and most common control method for fire ants is chemical insecticides, these still provide only temporary control (up to 1 year), can be detrimental to nontarget organisms, and often are not economical for large areas (Brown 1961, Barr and Drees 1996). Because of this, there has been a renewed interest in biological control agents for imported fire ants in the United States (Porter et al. 1995a, Cook et al. 1997, Williams et al. 1998).

The average densities of fire ant populations in the United States are more than 5 times higher than in their native South American habitats (Porter et al. 1997a). Biological factors (predators, parasites, pathogens, competitors) may be the major reasons for the differences in populations because factors such as climate, habitat, soil, and cultural practices do not explain intercontinental population differences. Thus, the higher densities of fire ants in the United States may be a result of their escape from natural enemies in South America. More than 30 natural enemies of fire ants have been discovered in South America, but these are almost entirely absent among the U.S. populations. (Jouvenaz et al. 1977, 1981; Jouvenaz 1983; Wojcik et al. 1987; Porter et al. 1997a).

Searches for effective biological organisms to control fire ants have been ongoing for many years (Allen and Buren 1974, Williams and Whitcomb 1974, Williams 1980); however, earlier results were not promising (Jouvenaz 1983, Wojcik 1990). Past attempts with biological organisms to control fire ants involved agents used as biopesticides, and these did not achieve consistent and effective control. Several agents have been evaluated, such as the straw itch mite, *Pyemotes tritici* (LaGrèze-Fosset and Montane) (Bruce and LeCato 1980, Jouvenaz and Lofgren 1986, Thorvilson et al. 1987); nematodes in the genera *Steinernema* Travassos and *Heterorhabditis* Poinar (Miller et al. 1988, Drees

et al. 1992); and the entomopathogenic fungus *Beauveria bassiana* (Balsamo) Vuillemin (Oi et al. 1994). Although producing mixed results, these organisms usually require direct application and contact with individual worker ants and therefore do not spread naturally to other fire ant colonies. They function more like biopesticides than self-reproducing biological control agents.

Self-sustaining biological control agents could become a major factor in long-term suppression of fire ant populations by causing direct mortality and/or becoming stress factors that reduce the ecological dominance of fire ants. If native ants can establish colonies and subsequently compete with fire ants, this should slow or halt the increase and expansion of fire ant populations. The ultimate result would be tolerable levels of fire ants with reduced pesticide use and increased arthropod diversity. Self-sustaining biological control agents also could be useful in natural habitats where pesticide use is not tolerated, or in harvested food crops, for which few registered fire ant baits are available. In addition, pastures and fields that are not maintained or disturbed contain a more diverse native ant fauna that could compete more successfully with biologically stressed fire ant colonies. Hence, the combination of natural control agents and competition from native ants should result in a sustained reduction in the overall fire ant populations.

Today, research on biological control of fire ants is being conducted by scientists in the U.S. Department of Agriculture, Agricultural Research Service (USDA-ARS) in several universities in the southern United States, and in a few private companies, and is concentrated on a few natural enemies (Figs. 2-5). It is hoped that these agents, if successful, will affect fire ant populations sufficiently to cause colony mortality and allow native ants to compete better.

The recent success with laboratory rearing, production, and field release of phorid flies, *Pseudacteon tricuspis* Borgmeier and *P. curvatus*

The higher densities of fire ants in the United States may be a result of their escape from natural enemies in South America.

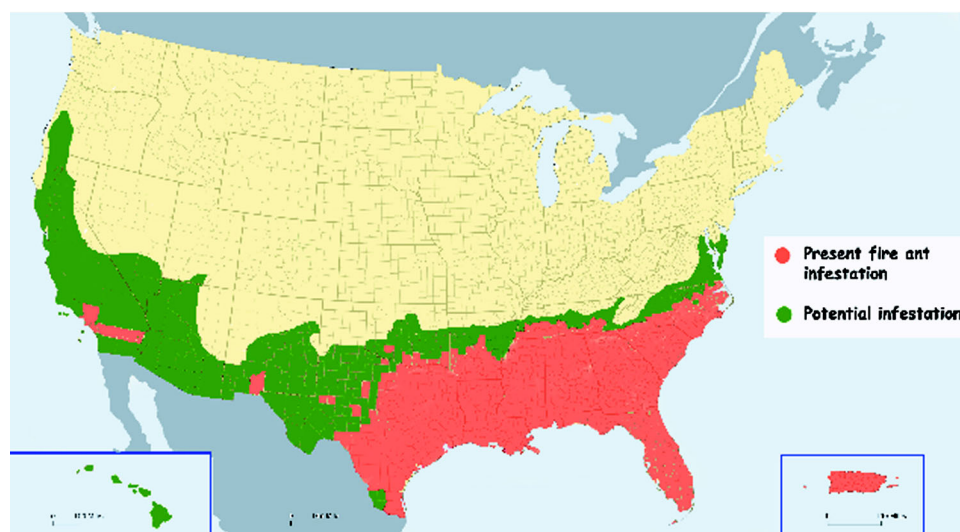


Fig. 1. Present (pink) (USDA-APHIS, 2003) and potential (green) (according to Korzukhin et al. 2001) infestation ranges for the imported fire ant in the United States.

The use of *S. daguerrei* as a biological control agent for imported fire ants will not advance until these problems are solved.



Fig 2. Parasitic ant, *Solenopsis daguerrei*, queen (arrow) seen on the back of a red imported fire ant, *Solenopsis invicta*, queen

Borgmeier in the United States (Porter et al. 1997b, Vogt et al. 2003) and the discovery of the microsporidium *Thelohania solenopsae* Knell, Allen, and Hazard in fire ant populations in the United States (Williams et al. 1998) have resulted in a resurgence in interest in the development and use of self-sustaining biological control organisms against fire ants. Both of these organisms are in field trials.

In this paper, we review the current status of biological pesticides and self-sustaining biological control agents for use against fire ants and present information on the possibilities for their future.

We also discuss some biological control organisms that have been or are under study.

Parasites

Social Parasitic Ant. A natural enemy of fire ants presently being studied is the parasitic ant, *Solenopsis daguerrei* (Santschi), formerly known as *Labauchena daguerrei*. This social parasite lacks a worker caste and produces only queens and males (Bruch 1930). *S. daguerrei* queens enter fire ant colonies and attach themselves to the colony queen (Fig. 2). Studies have shown that this parasite inhibits egg production by the fire ant queen, causing the ant colony to collapse and eventually die out (Silveira-Guido 1962; Silveira-Guido et al. 1963, 1964, 1965, 1967a, 1967b, 1968a, 1968b, 1969, 1973).

Field host range surveys indicate that *S. daguerrei* is at least genus-specific. In South America, this parasitic ant was found parasitizing *S. invicta*, *S. richteri*, *S. saevissima* (F. Smith), *S. macdonaghi* Santschi, and *S. quinquecupis* Forel (Silveira-Guido et al. 1973, Briano et al. 1997, Calcaterra et al. 2000a). *S. daguerrei* has not been found in field colonies of other ant genera in Argentina (Calcaterra et al. 2000a).

Large *S. daguerrei* populations in a fire ant colony result in a corresponding reduction in fire ant workers (Calcaterra et al. 1999). The presence of *S. daguerrei* in fire ant colonies also has detrimental effects on colony growth, the proportion of sexual reproductives produced in the colony,

and the number of host queens in polygyne colonies (Calcaterra et al. 1999, 2000a, 2000b). Because *S. daguerrei* queens attach themselves to fire ant queens, this parasitic species could be especially useful in controlling the multiple-queen form of the fire ant.

However, recent research with this organism in the United States (under quarantine) and in Argentina (Briano et al. 2002 [Au: Q1]) demonstrated the extreme difficulty in laboratory rearing, introduction into fire ant colonies, and conducting host-specificity studies. Although field-collected fire ant colonies parasitized by *S. daguerrei* were maintained in the laboratory for several months, eventually the parasite disappeared. All introductions of the parasite in laboratory and field studies failed. The use of *S. daguerrei* as a biological control agent for imported fire ants will not advance until these problems are solved.

Mites. The straw itch mite has been reported as a predator of imported fire ants. Bruce and LeCato (1980) reared mites on cigarette beetle [*Lasioderma serricorne* (F.)] pupae and applied 100 ml of beetle pupae to individual fire ant nests as the first progeny emerged from gravid female mites. A total of 47 nests were treated, and 33 were rendered inactive. Inactivity was determined by a lack of loose soil on the nest, an increase of grass growth on and around the nest, and the absence of ants running around [AU: OK?] when the nest was scrapped. However, no attempt was made to excavate the nests to determine mortality or collect dead ants.

Other studies with the mite (Collins and Bishop 1985, Jouvenaz and Lofgren 1986, Thorvilson et al. 1987) resulted in negligible control. Also, the straw itch mite is widely regarded as a pest and can cause severe dermatitis in humans (Mullen and OConnor 2002); [Au: Q2] thus, there is a risk to individuals handling the mites or persons exposed to mites following applications.

Bass and Hays (1976) observed another mite, *Tyrophagus putrescentiae* (Schrank), feeding on eggs of fire ants under laboratory conditions. It has not been established whether these mites prey on fire



Fig. 3. Phorid fly, *Pseudacteon tricuspis*, (arrow) attacking fire ant worker.

ant eggs under normal colony conditions.

Phorid Flies. Flies in the genus *Pseudacteon* (Porter 1998a) are a promising group for biological control of fire ants because they are highly specific in their host preferences (Porter et al. 1995a; Gilbert and Morrison 1997; Porter 1998b, 2000; Porter and Alonso 1999; Morrison and Gilbert 1999; Porter and Briano 2000), are broadly distributed across season, geography, and climate (Borgmeier and Prado 1975, Fowler et al. 1995, Porter 1998a, Porter et al. 2003), and affect fire ant behavior and probably populations (Feener and Brown 1992, Orr et al. 1995, Porter et al. 1995c). These parasitic flies attack individual workers (Fig. 3), stop fire ant foraging, and shift the local competitive balance to other ant species (Feener and Brown 1992, Orr et al. 1995, Porter et al. 1995c). The larvae of these flies decapitate their hosts and then pupate in the ant's head capsule (Porter et al. 1995b, Morrison et al. 1997).

About 20 species of *Pseudacteon* flies attack fire ants in South America (Porter 1998b, Porter and Pesquero 2001). Phorids are common and active throughout most of the year (Fowler et al. 1995, Morrison et al. 1999, Porter et al. 2003), but different species are more active at different times of the day (Pesquero et al. 1996) and attack different sizes of workers (Morrison et al. 1997, Morrison and Gilbert 1998).

A single fly can stop the foraging of hundreds of workers (Orr et al. 1995, Porter et al. 1995c, Mehdiabadi and Gilbert 2002). This reduction in foraging by fire ants should increase competition from other ants that would otherwise be excluded from food sources in fire ant territories (Feener and Brown 1992, Morrison 1999). The overall impact of these flies on fire ant populations is unknown; however, it is clearly sufficient to have caused the evolution of a number of phorid-specific defense behaviors. These behaviors could only have evolved if *Pseudacteon* flies had population-level impacts on the survival of fire ant colonies or the production of sexuals (Porter 1998b).

Other Parasites. The strepsipteran parasitoid of fire ants, *Caenochloax fenyesi* Pierce, described by Cook et al. (1996, 1997, 1998) has a complex life cycle and low parasitization rate, and thus, may not be a good candidate for biological control of fire ants. Future research with this organism may demonstrate its usefulness in biological control programs, but for now, it does not look promising.

Several species in the genus *Orasema* (Hymenoptera: Eucharitidae) parasitize fire ants in South America, and it has been suggested that some of these parasitoids, such as *Orasema xanthopus* (Cameron), might be useful in biological control of fire ants in the United States (Johnson 1988, Heraty 1994). Females of these parasites deposit their eggs on or into plant tissue that is visited by workers of the host ant. The larvae attach to either an ant or intermediate host insect and are brought to ant nests, where they then parasitize host larvae (Heraty et al. 1993, Heraty 1994).

Rigorous testing of oviposition habits would

be necessary because some species of *Orasema* damage crop plants. Also, as is true for many potential biological control agents, there is a lack of biological information about these parasites (Heraty 1994). Thus, additional studies are needed to determine whether they hold any promise for use against fire ants.

Pathogens

Microsporidia. The microsporidium, *Thelohania solenopsae*, an intracellular obligate pathogen (Fig. 4), was previously found only in South America (Knell et al. 1977), where it is the most common microbial enemy of native fire ants in Argentina (Briano et al. 1995a, 1995b). In 1996, it was discovered in the United States in limited locations within Florida, Mississippi, and Texas (Williams et al. 1998). Field-collected *T. solenopsae*-infected colonies of fire ants died faster than uninfected colonies (Briano and Williams 1997,

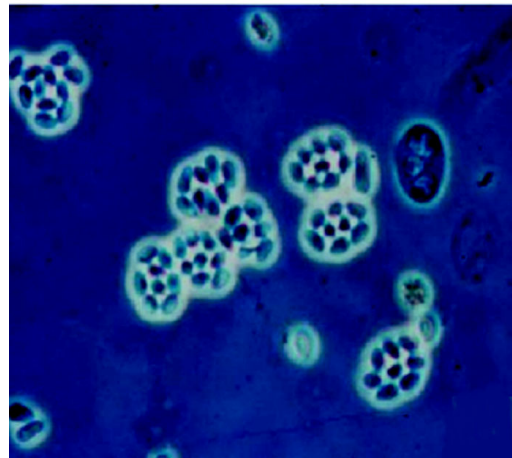


Fig. 4. Octospores of the microsporidium *Thelohania solenopsae* in octets seen under phase microscopy.

Knell et al. 1977). Laboratory colonies of *S. invicta* containing single and multiple queens that had been infected with this pathogen had declines in brood of 85–100% after 22–52 weeks and higher queen mortality (Williams and Oi 1998, Williams et al. 1999, Oi and Williams 2002).

Field studies on the impact of *T. solenopsae* on the black imported fire ant, *S. richteri*, in Argentina indicated an 83% decrease in the density of colonies after 4 years (Briano et al. 1995a). Cook (2002) reported nest sizes to be smaller from infected *S. invicta* colonies in Texas. In Florida, Oi and Williams (2002) reported fluctuating changes in infected *S. invicta* populations over a 2-year period, with a maximum reduction of 63%. They noted, however, that the field impact of this disease can be masked by reinfestations that may coincide with the slow decline of infected colonies. We also have observed [Au: correct?] that sustained field infections have only been found or initiated in what appear to be polygynous fire ant populations (unpublished data).

A rapid mortality of infected ants potentially indicates that this disease may have significant impact on fire ant populations, and might serve as a biological control for these pest ants.

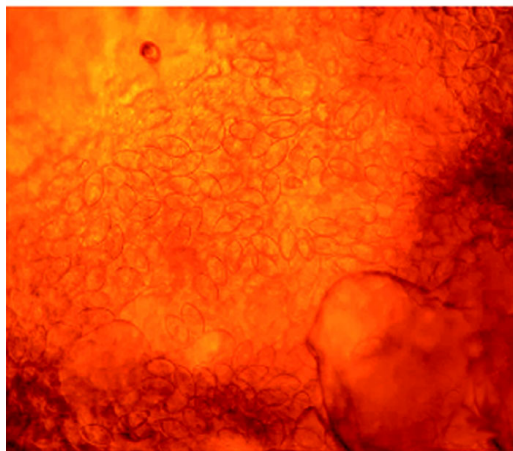


Fig. 5. Spindle-shaped spores of the neogregarine *Mattesia* sp., causing agent of the yellow head disease (YHD), as seen through the *S. invicta* cuticle under light microscopy.

This pathogen is transmitted transovarially (vertical transmission) from the queen to its progeny (Briano et al. 1996, Valles et al. 2002). The natural mechanism of horizontal transmission between colonies is unknown; however, horizontal transmission has been accomplished by inoculating colonies of *S. invicta* with infected fire ant brood. Williams et al. (1999) have demonstrated the natural spread of the pathogen from inoculated field colonies. *T. solenopsae* infects all stages of fire ants (Briano et al. 1996) and directly affects fire ant colonies by debilitating queens so they eventually cease production of new offspring (Williams et al. 1998). *T. solenopsae* is a promising new tactic for the control of fire ants. As a classical biological control agent, *T. solenopsae* has the potential to

- (1) be a long-term, environmentally compatible fire ant control tactic that is applicable to a broad range of systems where fire ant controls are not available;
- (2) reduce the reliance on pesticides by slowing reinfestations;
- (3) protect and conserve ecosystem quality and diversity by reducing fire ant dominance, thereby encouraging the establishment of native ants and other arthropods;
- (4) be used as a stress factor by increasing the susceptibility of *S. invicta* to other pathogens and natural enemies; and
- (5) be used in an integrated pest management program where infected fire ants would be more susceptible to pesticides.

Consequently, the amount of insecticide needed for control could be significantly reduced. For example, the activity of the entomopathogenic fungus *Beauveria bassiana* (Brinkman and Gardner 2000) was increased; and hydramethylnon, which is an active ingredient of a fire ant bait, was more effective in *T. solenopsae*-infected *S. invicta* (Valles and Pereira 2003).

In addition to *T. solenopsae*, another microsporidium that looks very promising against

fire ants is *Vairimorpha invictae* Jouvenaz and Ellis (Jouvenaz 1986a). Although the field prevalence of this pathogen was less than 2.5% in north-central Argentina, *V. invictae*-infected fire ant workers had 19–32% lower survivorship (Briano and Williams 2002). In previous observations, when laboratory fire ant colonies contained infections with both *T. solenopsae* and *V. invictae*, the detrimental effect on the colonies appeared faster than with a single infection. Recently, field plots have been established in northern Argentina and are being monitored to confirm detrimental effects of *V. invictae* and dual infections on *S. invicta*. Also, field host range studies in Argentina indicate that both microsporidia are specific to *Solenopsis* ants (Briano et al 2002). [Au: Q1]

A new disease of the imported fire ant has been discovered in Florida (Pereira et al. 2002). This disease, caused by a protozoan in the genus *Mattesia*, was named yellow-head disease (YHD) because of an atypical yellow–orange color of the heads of infected ants, which contain numerous spindle-shaped spores (Fig. 5). YHD is widely distributed in Florida in multiple-queen and single-queen fire ant colonies, being present in 34% of sites and in 8% of nests surveyed. [Au: Q3] The disease has also been confirmed from a colony in Gulfport, MS. Field colonies brought into the laboratory have had large mortality of YHD-infected ants. A rapid mortality of infected ants potentially indicates that this disease may have significant impact on fire ant populations, and might serve as a biological control for these pest ants.

Fungi. Entomopathogenic fungi have been investigated by several researchers. Broome (1974) and Broome et al. (1976) observed a mortality rate of 90% when *S. richteri* was exposed to *B. bassiana*. Stimac et al. (1993a, 1993b) and Pereira et al. (1993) investigated effects of a Brazilian strain of *B. bassiana* on fire ant colonies (Fig. 6) and demonstrated that this fungus provided some control of the treated colonies. However, Oi et al. (1994) did not get acceptable levels of control with *B. bassiana* in a series of field trials, and Callcott et al.



Fig. 6. *S. invicta* worker infected with the entomopathogenic fungus *Beauveria bassiana*.

(1988) also obtained poor results in a trial.

In another study, faster fire ant mortality was obtained by using an alginate formulation of *B. bassiana* (Thorvilson and White 1994). This strain was originally isolated from workers of the Mexican leafcutting ant, *Atta mexicana* (F. Smith), and when formulated in alginate pellets, effectively reduced field populations of fire ants (Bextine and Thorvilson 1998). *B. bassiana* has also been formulated in attractive baits and tested against fire ants. Ants were observed retrieving the bait, and fungal infection levels sharply increased after treatment with the bait. In one test, the economic impact of fire ants on harvested almonds was decreased by the fungal application (Pereira et al. 1995). Commercial formulations of biopesticides containing *B. bassiana* were being developed [Au: Q5] by SafeScience (now Glyco Genesys, Boston). A different formulation of the same fungal species has been commercialized by Troy Biosciences (Phoenix, Ariz.). In tests with another fungus, laboratory bioassays indicated that *Metarhizium anisopliae* (Metschnikoff) Sorokin caused 100% mortality of 15 fire ant queens after 5 days (Sanchez-Peña 1992).

Jouvenaz (1986b) reported an unidentified unicellular fungus that occurs in the hemolymph of *S. invicta*. The fungus was transmitted orally to healthy fire ant colonies. Although the cells may become very numerous in the hemolymph, there are usually no physical or behavioral signs of infection. Jouvenaz et al. (1977) found this organism in 9.23% of 1,007 colonies of *S. invicta* from six states.

Nematodes. The potential for entomopathogenic nematodes in the genus *Steinernema* (Fig. 7) to control fire ants has been investigated by a number of researchers. Poole (1976) determined in laboratory assays that larvae and pupae of fire ants are relatively susceptible to *Steinernema carpocapsae* (Weiser) Wouts, Mracek, Gerdin, and Bedding (referred to as *S. dutkyi*); whereas adult workers were much less susceptible. Quattlebaum (1980) reported that 1–2 million infective juvenile *S. carpocapsae* (strain DD-136) per mound killed 22–97% of treated colonies 2 weeks after treatment. Miller et al. (1988) achieved minimal control with this nematode in a series of field trials in Texas and Florida. Similarly, poor results were obtained by Collins et al. (1988) and by Jouvenaz et al. (1990). Collins and Lindregren (1990) evaluated a Mexican isolate of *S. carpocapsae* and noted that up to 15 million nematodes per fire ant colony did not result in mortality to adult workers, although infection and subsequent mortality of immatures were observed. Drees et al. (1992) reported that in field tests, a large number of fire ant colonies abandoned nematode-treated mounds, and this represents a limitation in the efficacy of nematodes.

Nickle and Jouvenaz (1987) reported that another species of nematode, *Tetradonema solenopsis* Nickle and Jouvenaz, parasitized *S. invicta* in Brazil. This nematode was found in 5 of 14 colonies collected in 1985. The authors noted that in the

most heavily parasitized colony, 12.5% of the adult workers were infected. Efforts to establish the nematode in laboratory colonies were not successful. Previous attempts to detect nematodes in surveys in the United States (Jouvenaz et al. 1977) and in Brazil (Jouvenaz et al. 1980) were not successful.

Bacteria. Several bacterial pathogens of other insects have been tested against imported fire ants, but none of these gave significant control (Broome 1974, Jouvenaz et al. 1980, Miller and Brown 1983, Jouvenaz 1990). Jouvenaz et al. (1980) noticed a possible bacterial infection in *S. invicta* in Brazil but attempts to isolate, culture, and transmit the infection were unsuccessful. Although bacteria have not shown much promise as biological control agents against imported fire ants, little has been done to evaluate them against fire ants; the few laboratory studies that were conducted involved the worker caste. Their effects on the immature stages of fire ants have been almost completely overlooked. Effects on immatures may be very important because fire ant larvae lack the filtering organ that prevents adults from ingesting solid particles as small as bacteria. Also, other larval Hymenoptera

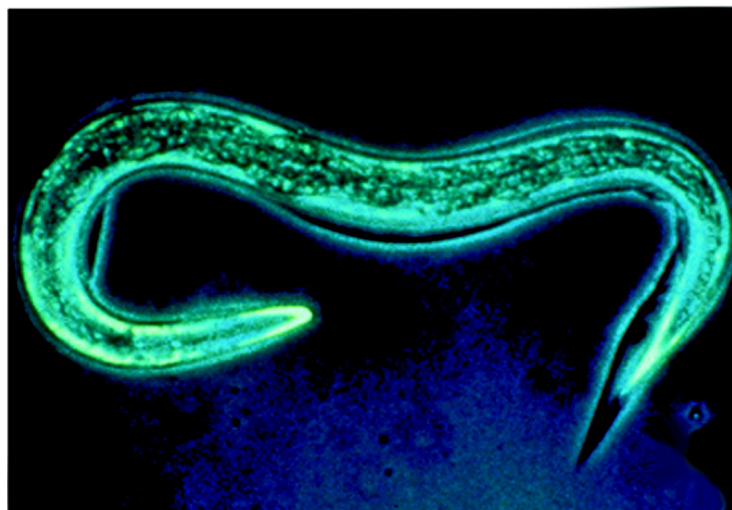


Fig. 7. Infective juvenile stage of the entomopathogenic nematode *Steinernema carpocapsae*.

are known to acquire bacterial diseases (Bailey and Ball 1991, Rose et al. 1999). The discovery and testing of bacterial pathogens for use against fire ants hold considerable promise for future biological control of these pests.

Viruses. Information about the use of viruses as control agents against the imported fire ant and ants in general is almost nonexistent. Research in this area has been neglected probably because of the difficulty in discovering candidates for testing, which is likely a result of their extremely small size.

Avery et al. (1977) reported a viruslike particle found in an unidentified fire ant taxonomically close to *S. invicta* and *S. saevissima* from Brazil. The colony of ants had been collected because they were infected with a microsporidian, and later observations with an electron microscope revealed the

Like bacteria, viruses may be an excellent agent for the biological control of imported fire ants, but little effort has been put into this area of research.

viruslike particle. Although the mortality of this colony was increased, it was uncertain whether this was a result of the infection with the microsporidian, the viruslike particle, or both. The infection was not detected in live workers.

Like bacteria, viruses may be an excellent agent for the biological control of imported fire ants, but little effort has been put into this area of research. Recently, however, at the USDA-ARS Center for Medical, Agricultural, and Veterinary Entomology (CMAVE) in Gainesville, FL, we have begun an intensive search for viruses in fire ants that might be useful in biological control.

Predators and Competitors

Predators and competitors of imported fire ants have not offered much hope in acting as major stress or control agents of these pest ants. Buren et al. (1978) proposed that predators of newly mated queens might be used to manage imported fire ant populations; however, considering the imported fire ants' explosive colony growth, extremely high reproductive potential, and ability to quickly colonize disturbed habitats, it is highly unlikely that predators could be successful.

Imported fire ants do suffer predation from some [AU: OK?] species that have some impact, albeit small. For example, during the mating and nest-founding period, imported fire ant queens are subject to predation by numerous general insect predators such as birds, dragonflies (Glancey 1981), and spiders (Whitcomb et al. 1973).

Several species of *Solenopsis* (*Diplophoptrum*) are important natural enemies of colony-founding imported fire ant queens in Texas (MacKay and Vinson 1989). Thompson (1980) found that these predaceous ants are present in large numbers in Florida in all but extremely hydric habitats. These subterranean ant predators readily kill and consume colony-founding fire ant queens as do other ant species, such as *Dorymyrmex medeis* Trager (cited as *Conomyrma insana* in Nickerson et al. 1975).

The black widow spider, *Latrodectus mactans* F., is also a major predator of fire ants. In one study in Texas cotton fields, fire ants constituted 75% of black widow prey (Nyffeler et al. 1988). The serendipitous placement of an *Argiope aurantia* Lucas (black and yellow garden spider) web in the flight path of emerging alate fire ants disrupted the mating flight of 15% of the observed queens, either through direct predation or by hampering their ability to fly (Lockley 1995).

Because of the extremely high reproductive potential (>240,000 fire ant alate females per hectare, according to Morrill [1974]), Jouvenaz et al. (1981) seriously questioned the ability of opportunistic general predators to suppress fire ant populations and doubted that biological control could be achieved by manipulating populations of these predators. The introduction of competitor ant species was proposed by Buren (1983), but this strategy is considered extreme because introducing new exotic ants could present problems as bad as or

worse than *S. invicta*. Finally, the technical difficulties and the potential for environmental damage of importing non-host-specific predators and competitor ant species into the United States are too hazardous to undertake.

The Potential of Biological Control

Several potential biological control agents have been reported to have negative effects on fire ant colonies. The successful establishment of biological control agents of fire ants would be a major benefit throughout the southern United States. For example, biological control agents would be especially useful in grazed lands and crops for which most baits are not registered for use. They also could be used in wildlife refuges and preserves where many of the current wide-spectrum baits are not environmentally acceptable, as well as being cost-prohibitive. Biological control agents could also help slow the spread of these pests into other susceptible states, such as Kentucky, Maryland, Virginia, Delaware, New Mexico, Arizona, Nevada, other parts of California, and up the Pacific Coast. Successful releases of biological control agents such as phorid flies, microsporidia, and other natural enemies could possibly shift the dominance from fire ants to native ants. If this happened, fire ant populations in the United States could be reduced and would possibly mirror densities of those in South America.

The development of new technologies using biologically based strategies will be important for the future management of fire ants. These could include more efficacious, self-sustaining biological control agents, biopesticides, semiochemicals (pheromones) to disrupt colony organization, genetic and molecular manipulation of colony organization, and exploitation of male sterility to affect colony reproduction. Biological control has the potential to offer long-term suppression of fire ants over large areas in the United States. Although eradication of the fire ant in the United States using chemicals and/or natural enemies will not occur by any known technology, natural control agents could reduce the fire ant population levels so that problems caused by these pests are greatly diminished. If successful, these programs would save millions of dollars annually by reducing the use of pesticides, greatly benefiting human health and the environment. Finally, reducing fire ant populations would help to reestablish the natural biodiversity that was present in many areas before the arrival of these invasive species.

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